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MORPHOLOGY OF THE BLOOD CORPUSCLES.

BY CHARLES-SEDGWICK MINOT.

IF one goes through the very extensive literature dealing with blood corpuscles one finds the most divergent views defended, and can hardly reach clear ideas, for the conceptions do not agree among themselves, either as to their structure or as to the development of the corpuscles. According to some the red corpuscles arise from the white; according to others the white corpuscles arise from the red; and according to still others both kinds arise from indifferent cells. In regard to one point only is the majority of investigators united,—namely, in the silent assumption that all blood corpuscles are of one and the same kind in spite of the absence of the nucleus in mammalian corpuscles. It is just this assumption that has caused endless confusion, and the morphology of the blood corpuscles can be cleared up only by starting with the recognition of the fundamental difference between nucleated and non-nucleated corpuscles. Farther, it must be recognized that no corpuscles, neither red nor white, arise from nuclei.

The origin of red corpuscles from nuclei has been maintained several times. This notion is based upon defective observations. It is very easy in the chick, for example, to convince oneself that the first blood corpuscles are cells; in the area vasculosa, at the time of the blood formation, the red blood-cells are readily seen, in part lying singly, in part in groups (blood islands), adherent to the vascular walls; the free cells are constituted chiefly by the nucleus, which is *surrounded by a very thin layer of protoplasm*, which is very easily overlooked, especially if the preparation is not suitably stained; this explains, I think, the statement made by Balfour (Works, Vol. I.) and others, that the blood corpuscles consist only of nuclei. By following the development along further we find that the protoplasm enlarges for several days, and that during the same time there is a progressive diminution in size of the nucleus, which, however, is completed before the layer

of protoplasm reaches its ultimate size. The nucleus is at first granular, and its nucleolus, or nucleoli, stands out clearly; as the nucleolus shrinks it becomes round, and is colored darkly and almost uniformly by the usual nuclear stains. This species of blood corpuscle occurs in all vertebrates, and represents the *genuine blood-cells*. According to the above description we can distinguish three principal stages: 1, young cells with very little protoplasm; 2, old cells with much protoplasm and granular nucleus; 3, modified cells with shrunken nucleus, which colors darkly and more uniformly. I do not know whether the first form occurs in any living adult vertebrate, although the assumption seems justified that they are the primitive form. On the other hand, the second stage is obviously that characteristic of the Ichthyopsida in general, while the third form is typical for the Sauropsida. Therefore the development of the blood-cells in amniota offers a new confirmation of Louis Agassiz's law (Haeckel's *Biogenetisches Grundgesetz*).

The blood-cells of mammals pass through the same metamorphoses as those of birds; for example, in rabbit embryos the cells have reached the Ichthyopsidan stage on the eighth day; two days later the nucleus is already smaller, and by the thirteenth day has shrunk to its final dimensions.

The white blood corpuscles appear much later than the red cells, and their exact origin has still to be investigated, for it has not yet been determined where they first arise in the embryo; nevertheless we may venture to assert that they arise outside the vessels. The formations of leucocytes outside of the vessels is already known with certainty to occur in later stages, as well as in the adult. The sharp distinction between the sites of formation of the red and white cells appears with especial clearness in the medulla of bone in birds, as we know from the admirable investigations of J. Denys (*La Cellule*, Tome IV.). The white blood corpuscles, then, are cells, which are formed relatively late, and wander into the blood from outside.

The non-nucleated blood corpuscles of adult mammals are entirely new elements which are peculiar to the class, and arise neither from red nor yet from white blood-cells. Their actual

development was first discovered, so far as I know, by E. A. Schäfer, who has given a detailed account of the process in the ninth edition of Quain's Anatomy, and has shown there a full appreciation of the significance of his discovery. Unfortunately Schäfer's important investigations have received little attention. Kuborn has recently confirmed Schäfer's results in an article (*Anatom. Anzeiger*, 1890) on the formation of blood corpuscles in the liver. One can readily study the process in the mesentery and omentum of human and other embryos. The essential point of Schäfer's discovery is that the non-nucleate corpuscles have an *intra-cellular* origin, and arise by differentiation of the protoplasm of vasoformative cells. Several corpuscles arise in each cell without participation of the nucleus; they are, therefore, specialized masses of protoplasm, and may perhaps best be compared to the plastids of botanists. I venture to propose the name of blood-plastids for these structures, since the term corpuscle (globule, Körperchen) has no definite morphological meaning.

Sonsino (*Arch. Ital. Biol.* XI.) affirms that the red blood-cells transform themselves into plastids. I have, however, never been able to find the intermediate forms in my own numerous preparations. I deem it probable that he has seen merely the degenerating stages of the red cells.

The present article is an abstract of a communication made in August last to the American Association for the Advancement of Science. Since then Howells' memoir on the blood corpuscles has appeared (*Journal of Morphology*, IV., 57). The author describes the ejection of the nucleus from the red cells, and believes that this results in the formation of red plastids. The process is, I think, really degenerative, and the resemblance between the non-nucleated body of the cell and a true plastid is not one of identity. Certainly, until proof is offered that the observations of Schäfer, Kuborn, and myself upon the intra-cellular origin of the plastids are proved erroneous, the emigration of the nucleus of the red-cells cannot be held to result in producing plastids, but only to be degenerative. That the red cells degenerate and disappear has been known; Howells' valuable observations indicate the method of their destruction.

The above review shows that the vertebrate blood corpuscles are of three kinds: 1, red cells; 2, white cells; 3, plastids. The red and white cells occur in all (?) vertebrates; the plastids are confined to the mammals. The red cells present three chief modifications; whether the primitive form occurs in any living adult vertebrate I do not know; the second form is persistent in the Ichthyopsida, the third form in the Sauropsida. According to this we must distinguish:

- A.—ONE-CELLED BLOOD, *i. e.*, first stage in all vertebrates; the blood contains only red cells with little protoplasm.
- B.—TWO-CELLED BLOOD, having red and white cells; the red cells have *either* a large, coarsely granular nucleus (Ichthyopsida), or a smaller, darkly staining nucleus (Sauropsida, mammalian embryos).
- C.—PLASTID BLOOD, without red cells, but with white cells and red plastids; occurs only in adult mammals.

Mammalian blood in its development passes through these stages, as well as through the two phases of stage B, all in their natural sequence; the ontogenetic order follows the phylogenetic.

I pass by the numerous authors whose views conflict with mine, partly because the present is not a suitable occasion for a detailed discussion, partly because those authors who have asserted the origin of one kind of blood corpuscle by metamorphosis from another have failed to find just the intermediate forms; it seems to me, therefore, that most at least of the opposing views collapse of themselves.